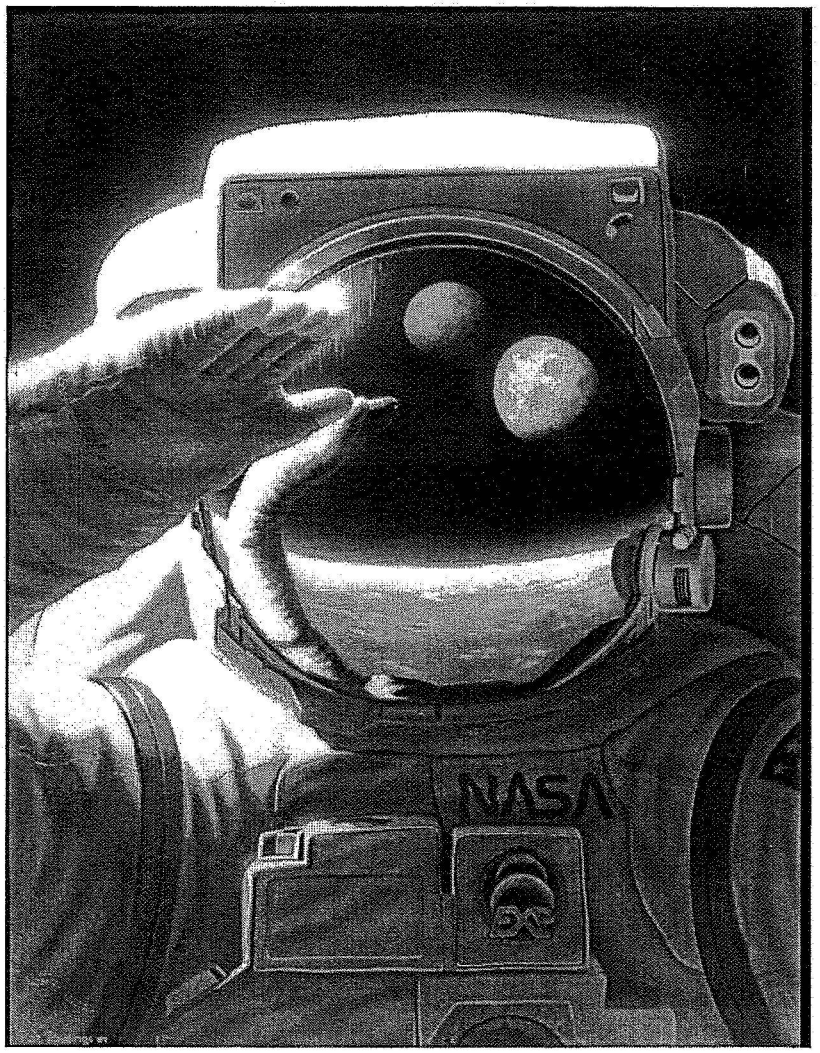
To Mars by Way of the Moon

Background from the

Exploration Systems Interim Strategy

National Aeronautics and Space Administration



Presented to the Georgia Tech Mars Society

November 4, 2004

Joyce Carpenter

Johnson Space Center

The Vision for Space Exploration

The Vision for Space Exploration defines a new U.S. space exploration policy. In support of this policy, through a renewed spirit of discovery, NASA will:

- Implement a sustained and affordable human and robotic program to explore the Solar System and beyond

- Extend human presence across the Solar System, starting with a human return to the Moon by the year 2020, in preparation for the human exploration of Mars and other destinations

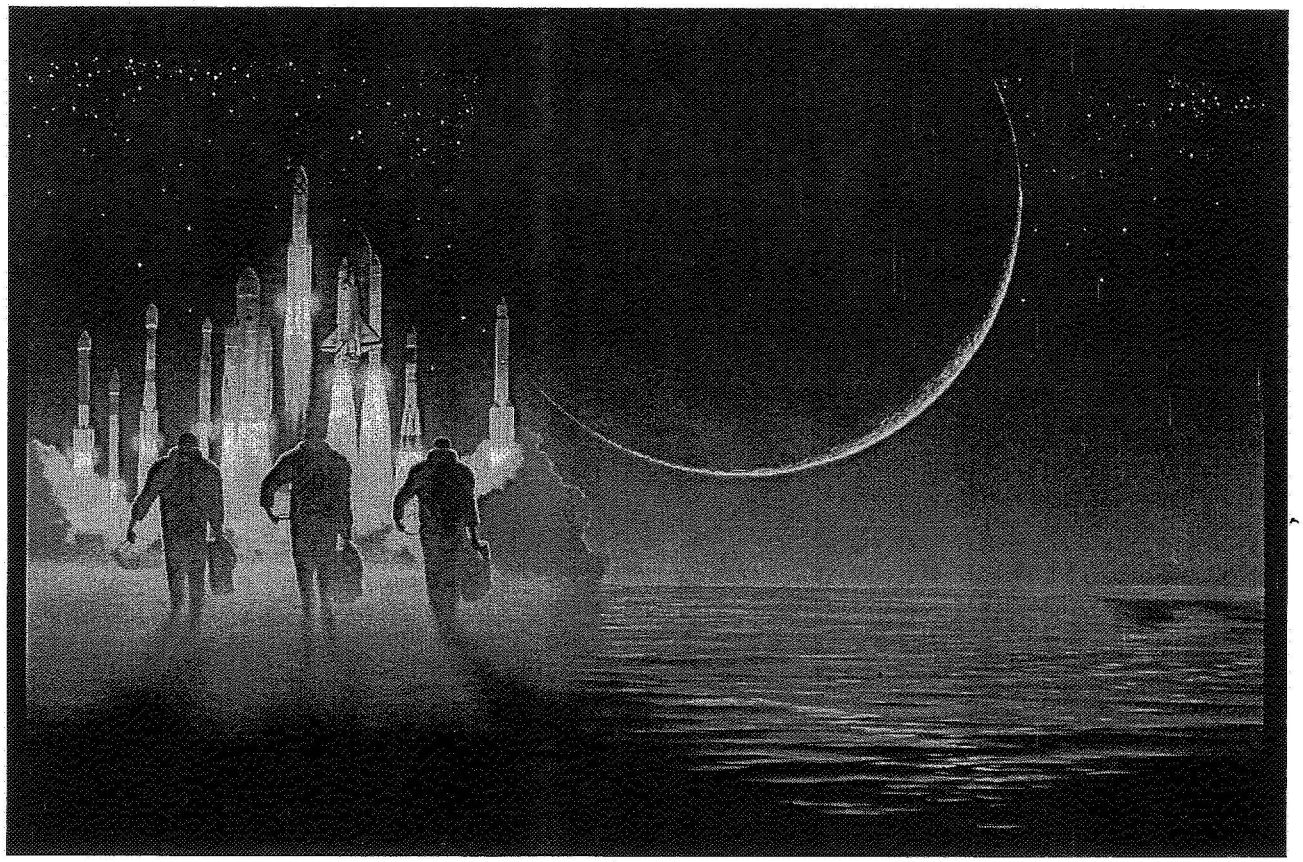
- Develop the innovative technologies, knowledge, and infrastructures both to explore and to support decisions about destination for future human exploration

- Promote international and commercial participation in exploration to further U.S. scientific, security, and economic interests

Requirements: The First Step in Exploring

Like the fictional Admiral James T. Kirk of the Starship Enterprise, all explorers aim "to boldly go where no one has gone before."

Every explorer initially imagines a journey, but to actually explore there must be a real vessel. Depending on the desire for capacity or speed or even luxury along the route, a different selection may result. Like the adventurers of old, NASA must determine what is important and, in so doing, establish a set of "requirements" for exploration missions. Thus, requirements formulation is the first step in a bold journey of exploration.

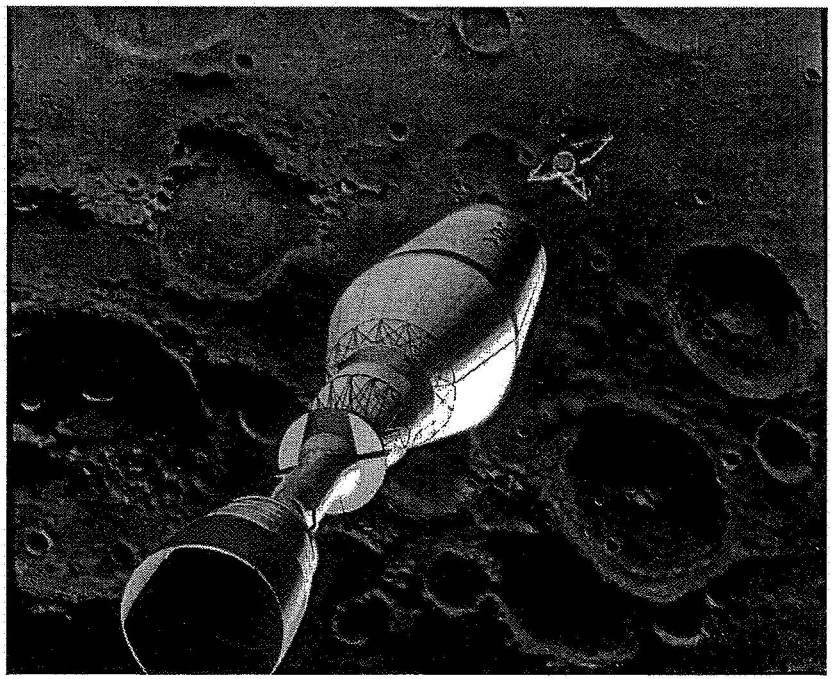


Creating System-of-Systems Capabilities for Sustained Exploration on the Moon and Beyond

• **Robotic Precursor Systems:** The first steps in our journey of exploration will be taken by robotic systems: orbiting, landing, and operating on the Moon as precursors to later human explorers.

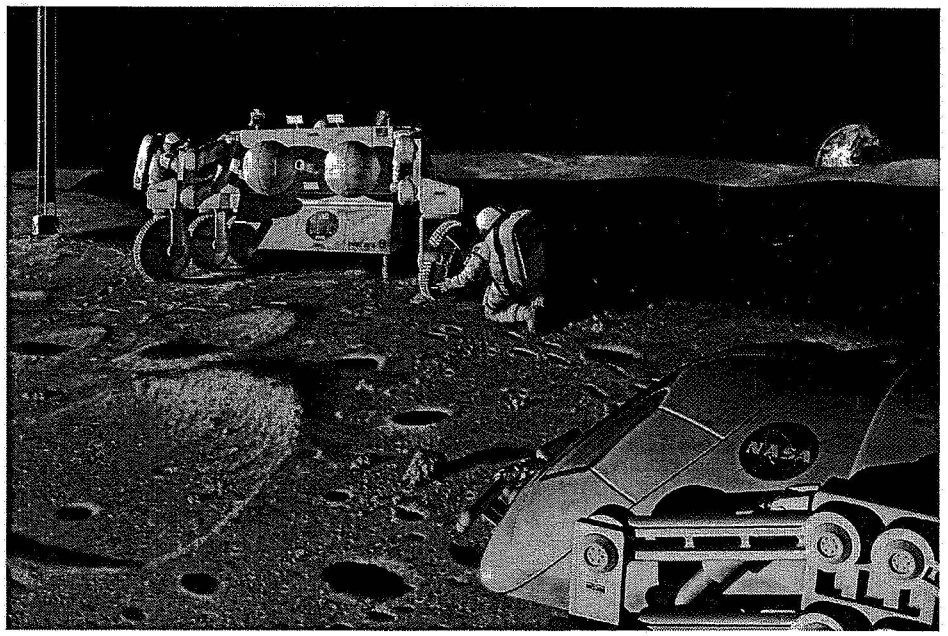
• **Crew Transportation:** The initial focus for the Constellation Systems Program will be to develop a Crew Exploration Vehicle (CEV) that will carry future astronauts from Earth to space, and from point-to-point in space. Initial high-level milestones include a CEV demonstration flight in 2008, a CEV flight without crew in 2011, and a CEV flight with crew in 2014.

Cargo Transportation: The cargo may include fuel and supplies, as well as transportation modules and supporting infrastructure that will be used in space or on the lunar surface. Multiple components may be launched from Earth, assembled in Earth orbit or other locations, and then transported for use in lunar orbit or on the Moon.



Creating System-of-Systems Capabilities for Sustained Exploration on the Moon and Beyond

• **Surface Systems:** The capabilities deployed on the lunar surface will support diverse mission phases, including lunar landing, surface operations, and ascent from the lunar surface. The variety of system-of- systems needed are still being defined, but could include systems for surface mobility, robotic assistants, extravehicular activity, habitation, scientific platforms such as telescopes, and surface-based power generation.

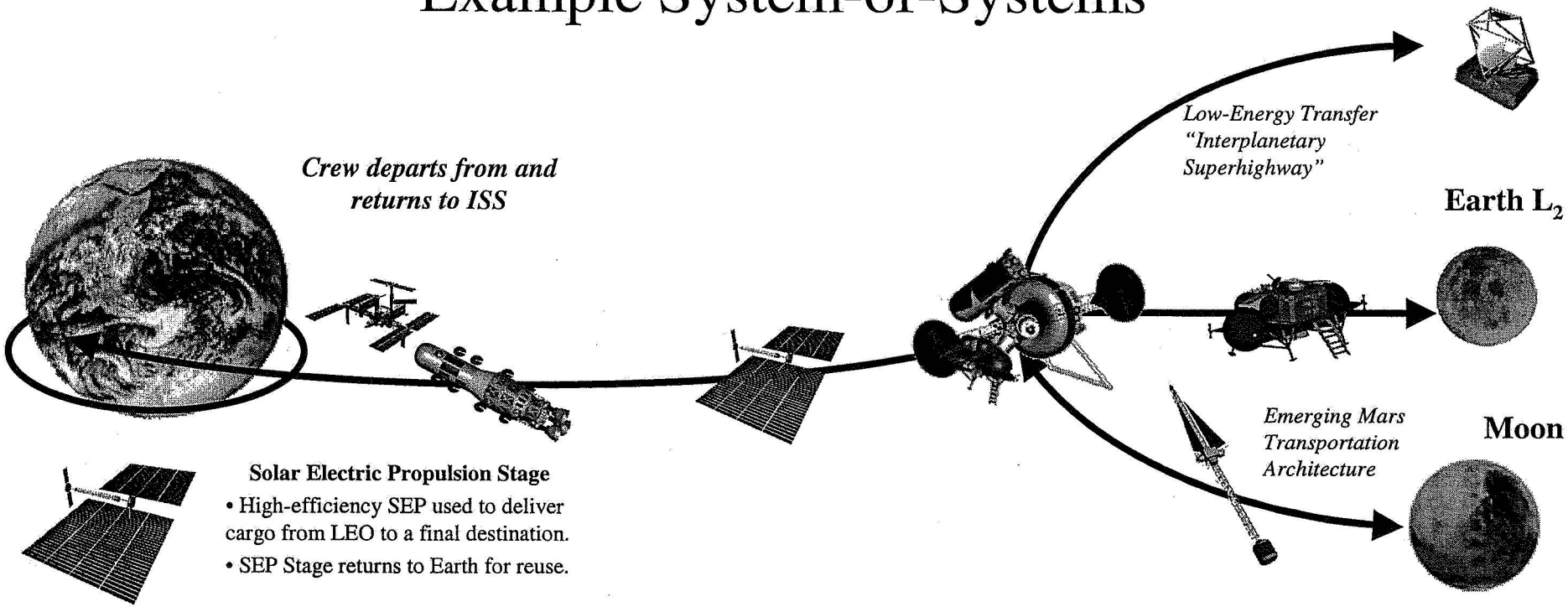


• **In-Space Systems:** NASA's space-based infrastructure may include additional communication networks, service platforms for maintenance and supply, and zero gravity extravehicular capabilities like evolved space suits.

• **Ground Systems:** NASA's existing or enhanced ground-based systems will support mission operations, preflight integration and logistics, and mission simulation and testing.

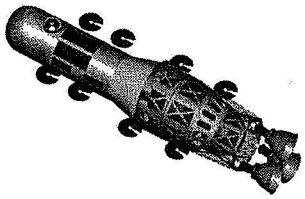
• **Humans as a Critical System:** New capabilities will focus on the human interface so that humans can live and work in space productively without suffering long-term health consequences.

Example System-of-Systems



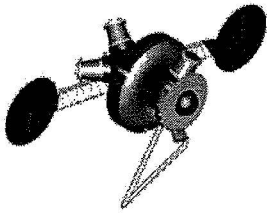
Solar Electric Propulsion Stage

- High-efficiency SEP used to deliver cargo from LEO to a final destination.
- SEP Stage returns to Earth for reuse.



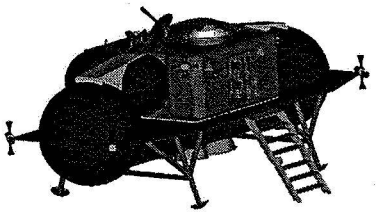
Crew Transfer Vehicle

- Transports crew between ISS and Lunar L_1 (4-6 day trip)
- Nominal return to ISS with contingency direct Earth return



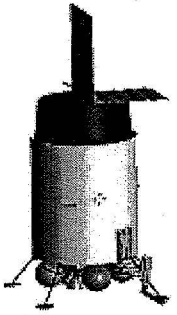
L_1 Outpost

- "Gateway" to the Lunar surface
- Outpost for staging missions to Moon, Mars and telescope construction



Lunar Lander

- Transports crew between Outpost and Lunar Surface
- 9-day mission (3 days on Lunar surface)



Lunar Habitat

- 30-day surface habitat placed at Lunar South Pole

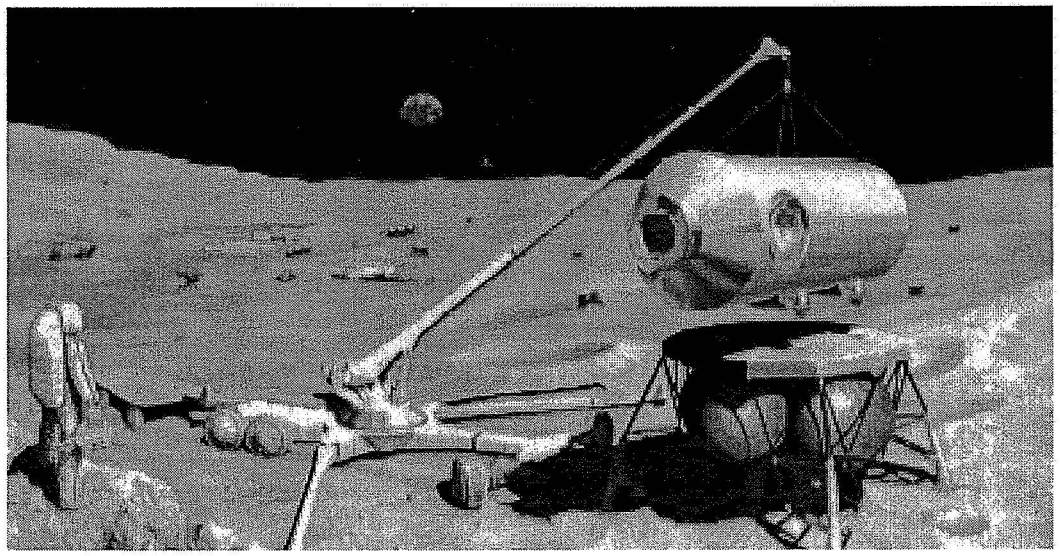
Using the Moon as a Test Bed for Future Exploration

The Moon will be used to develop and test new exploration approaches, technologies, and systems that can be used to improve reliability and advance exploration capabilities for many future destinations.

The Moon offers a convenient test location far enough from home to be challenging, but not so far as to limit its usefulness as a location for development and testing.

For many new systems, core components will be developed that can be used in multiple architectures at diverse destinations. Systems and components will be tested on and near the Moon to determine how they operate in harsh lunar and space environments.

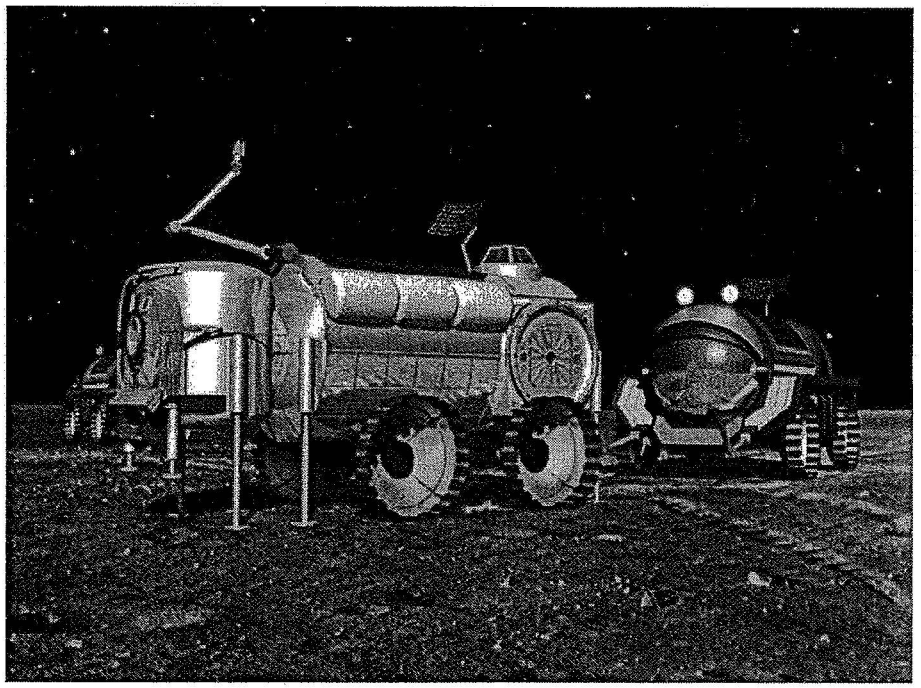
The Moon will also provide the opportunity to understand how crews adapt and perform in a partial-gravity environment. Before deploying essential systems to more distant destinations, we will ensure that the systems can operate without immediate assistance from Earth. This will be of particular importance for human life support systems that will be relied upon for missions to Mars and other distant locations in the Solar System.



Using the Moon as a Test Bed for Future Exploration

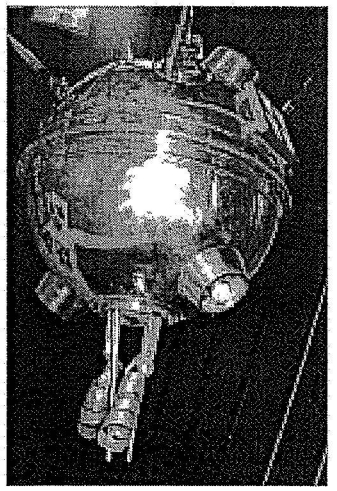
New designs for efficient and effective flight and surface operations will also be evaluated. In addition, we will analyze the use of lunar and other space resources for power generation, propulsion, and life support.

As we use the Moon as a test bed for future exploration, we will also seek to advance discovery and understanding by conducting scientific experiments on the Moon that help resolve fundamental questions about the origin and evolution of the Moon, the Earth, and the Solar System. We also may use the lunar environment as a location to learn more about meteors, asteroids, comets, and other astronomical phenomena.

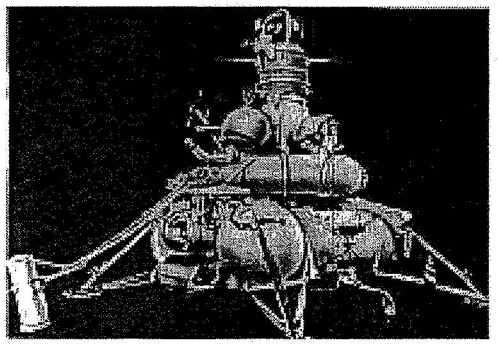


Haven't We Been to the Moon Before?

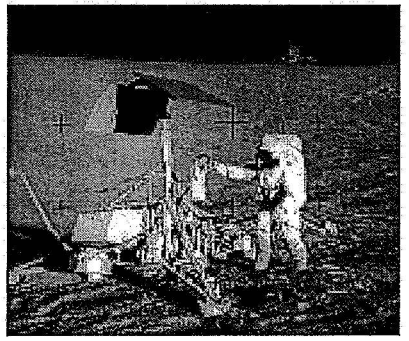
- First Lunar exploration missions consisted of robotic flybys, impactors, orbiters, and soft landers
  - Luna 1-24, Zond 1-8 (1959-1976) [Russia]
  - Pioneer 4 (1959) [USA]
  - Ranger 1-9 (1961-1965) [USA]
  - Surveyor 1-7 (1966-1968) [USA]
  - Lunar Orbiter 1-5 (1966-1967) [USA]
- Took first pictures of the Moon, including the far side
- Made detailed maps of the surface
- Returned Lunar soil samples (Luna 16, 20, 24)
- Determined the surface composition
- Paved the way for future human exploration



Luna 1



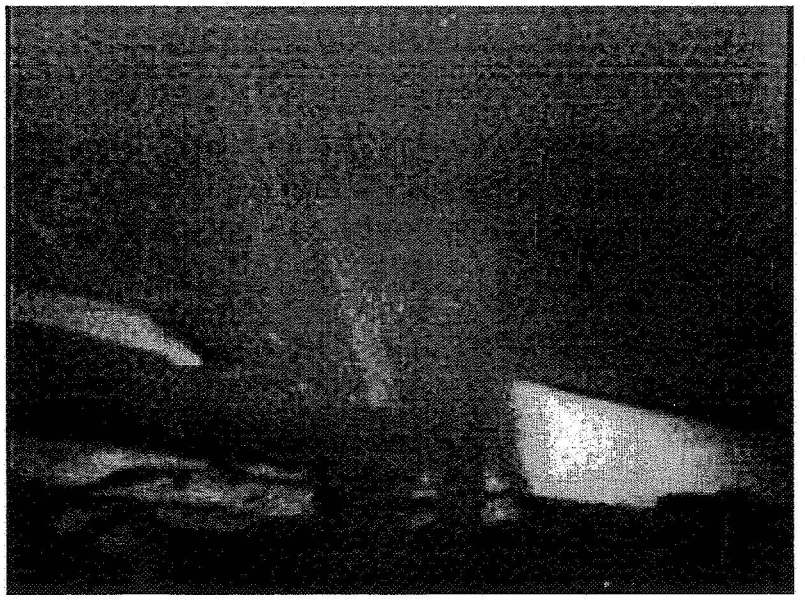
Luna 16

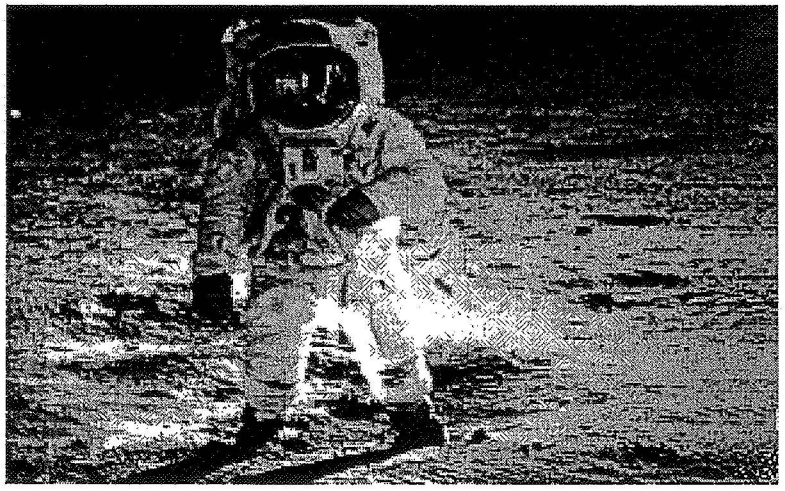


Surveyor 3

One Small Step…

- On July 20, 1969, Neil Armstrong and Buzz Aldrin took the first steps by a human on the Moon
- Ten astronauts followed to a number of interesting locations on the Moon

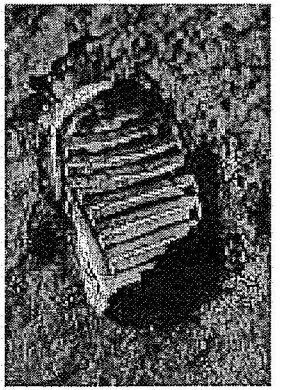




Buzz Aldrin at Mare Tranquillitatis

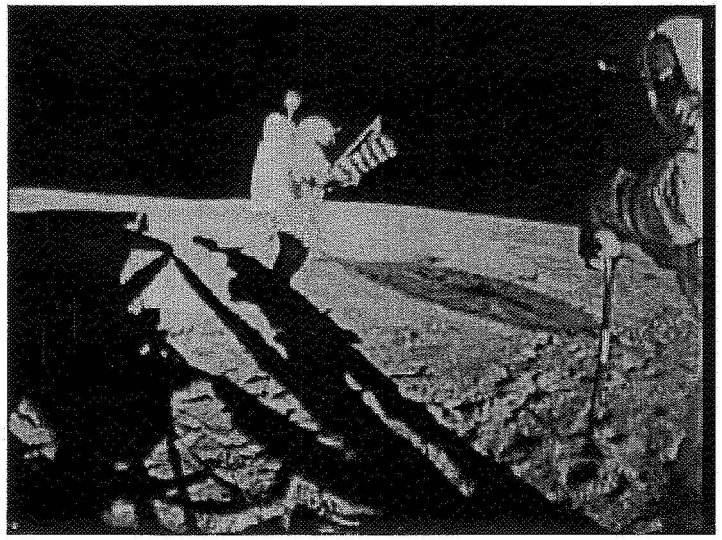
The Astronauts:

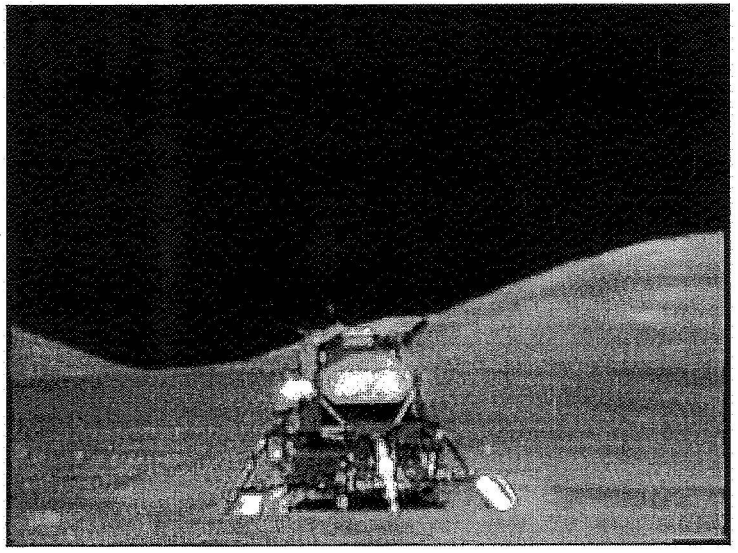
- Deployed science instruments
- Collected samples (Moon Rocks)
- Explored the terrain
- Took pictures
- Planted a flag
- Drove a car
- Played golf



Apollo's Accomplishments

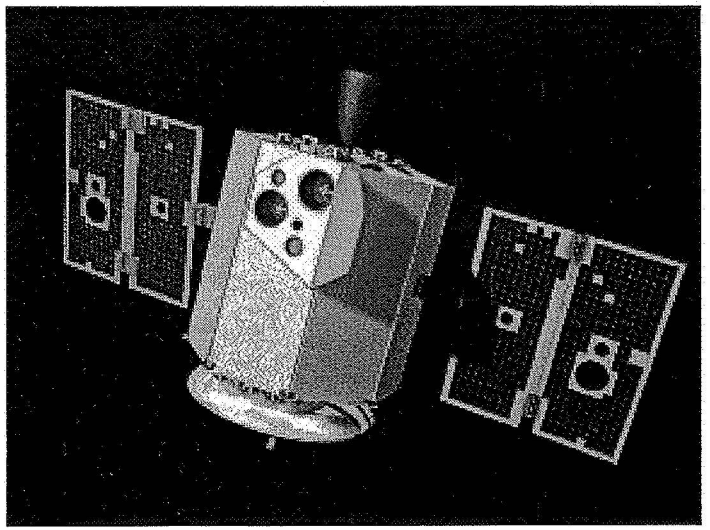
- Returned 800 lb of Lunar samples for detailed study on Earth
- Developed technologies to be used in everyday life
  - Microcomputers
  - Advanced Materials
  - Photography
  - Velcro, Tang
- Overcame a number of problems, some of which were life-threatening problems
- Took the first steps on a new world and began man's journey beyond Earth





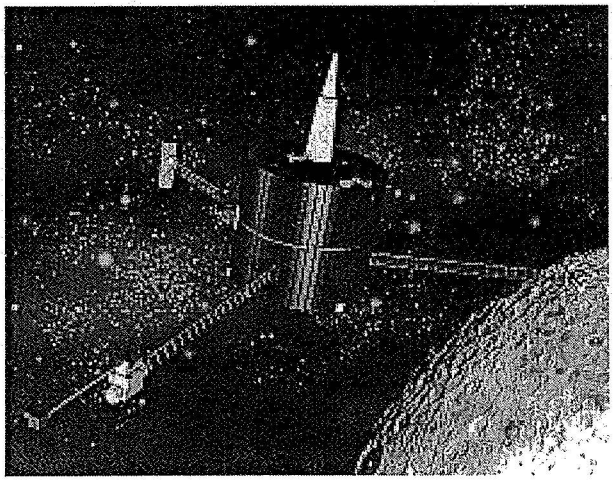
Recent Exploration

- Clementine (1994)
  - Mapped the entire Lunar surface at a number of resolutions and wavelengths
  - Discovered permanently shadowed impact craters at north and south pole
  - Suggested these craters may contain vast quantities of ***water ice!***



Clementine

- Lunar Prospector (1998)
  - Measured density of hydrogen atoms (water) at Lunar poles
  - Investigated the evolution of the Moon
  - Measured crustal magnetic field and induced magnetic dipole
  - Searched for source of Lunar atmosphere



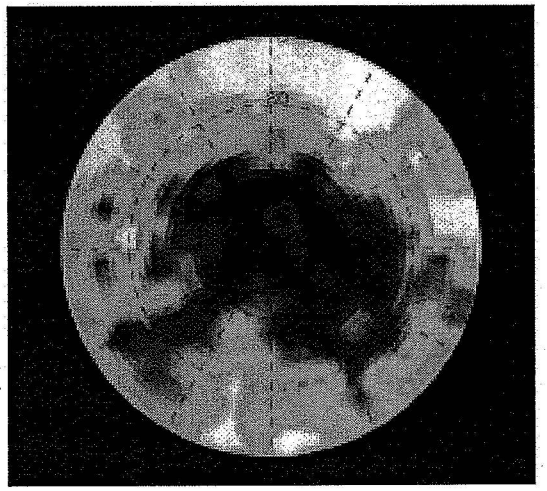
Lunar Prospector

A Possible Destination on the Moon: The South Pole

The south pole of the Moon is one of our possible destinations for extended lunar exploration. Remote sensing spacecraft in 1994 and 1998 identified polar cold traps on the lunar surface—in permanent shadow—as likely containing hydrogen, possibly as water ice. If the presence of hydrogen and other important elements is confirmed, lunar materials could be made into propellants, breathable air, and other consumables, reducing the dependence of future human missions on a logistics train extending from Earth and enabling a truly system-of-systems impact on the overall space exploration vision.

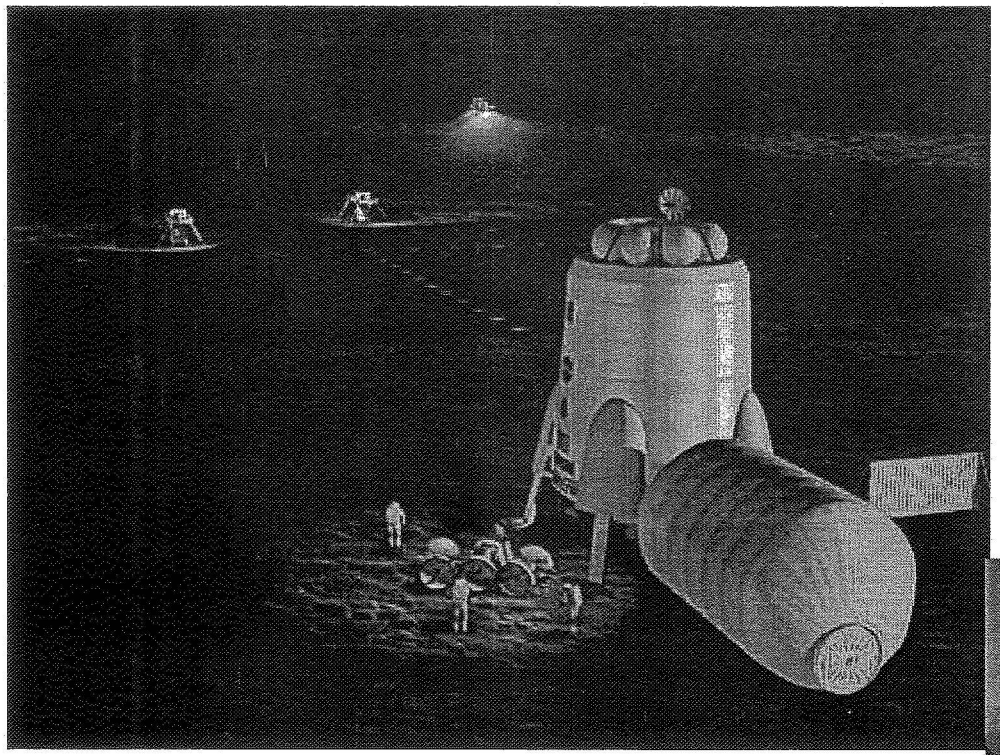
Making use of this space resource would require extensive effort. We would first have to function as "prospectors," confirming where the water is and determining its composition. Then, as "miners," we would have to excavate water-bearing "ore" from craters and then remove the water and other useful material. This will require the development of low-gravity mining and beneficiation technologies that are analogous to those on Earth, but with challenging twists, including the requirement that they operate at low gravity (1/6th g) and in extreme cold (-200° C).

In this manner, the Moon would be used for testing and reducing the risks associated with developing space-based resources in other locations in the Solar System like Mars. Carbon dioxide in the Martian atmosphere, and water ice available near the poles, could be tapped to provide air for visiting expeditions and propellant for the return trip home. This could reduce the resources that would otherwise have to be launched from Earth in support of those future missions.

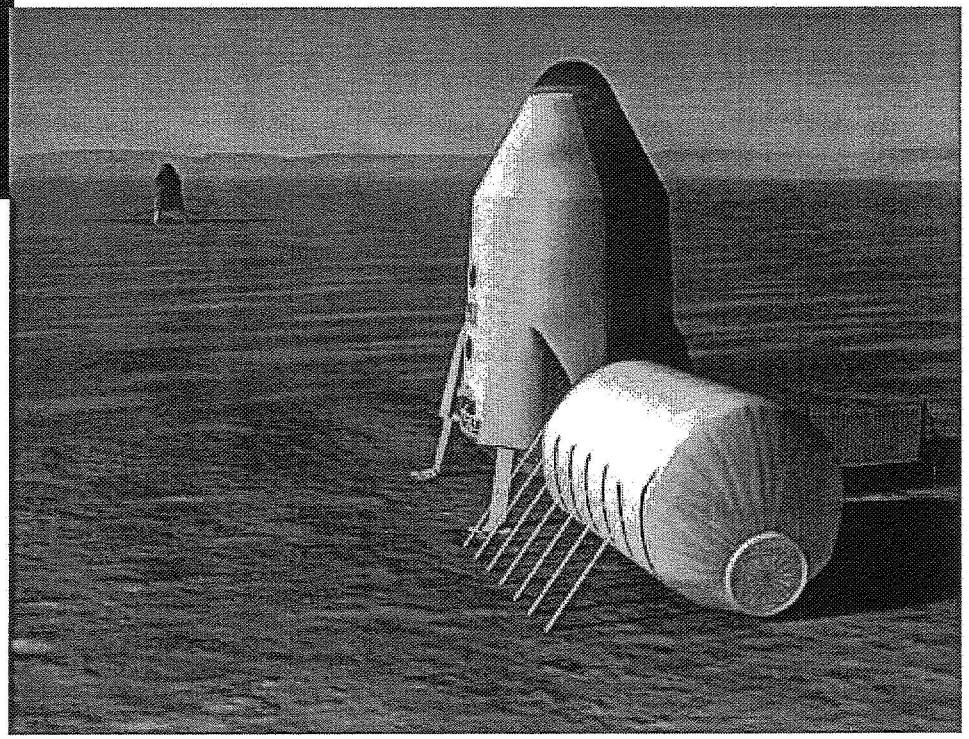


A false color map of the Moon indicating the presence of hydrogen in blue. The south pole is at the center of the image.

Systems Test Bed For Mars

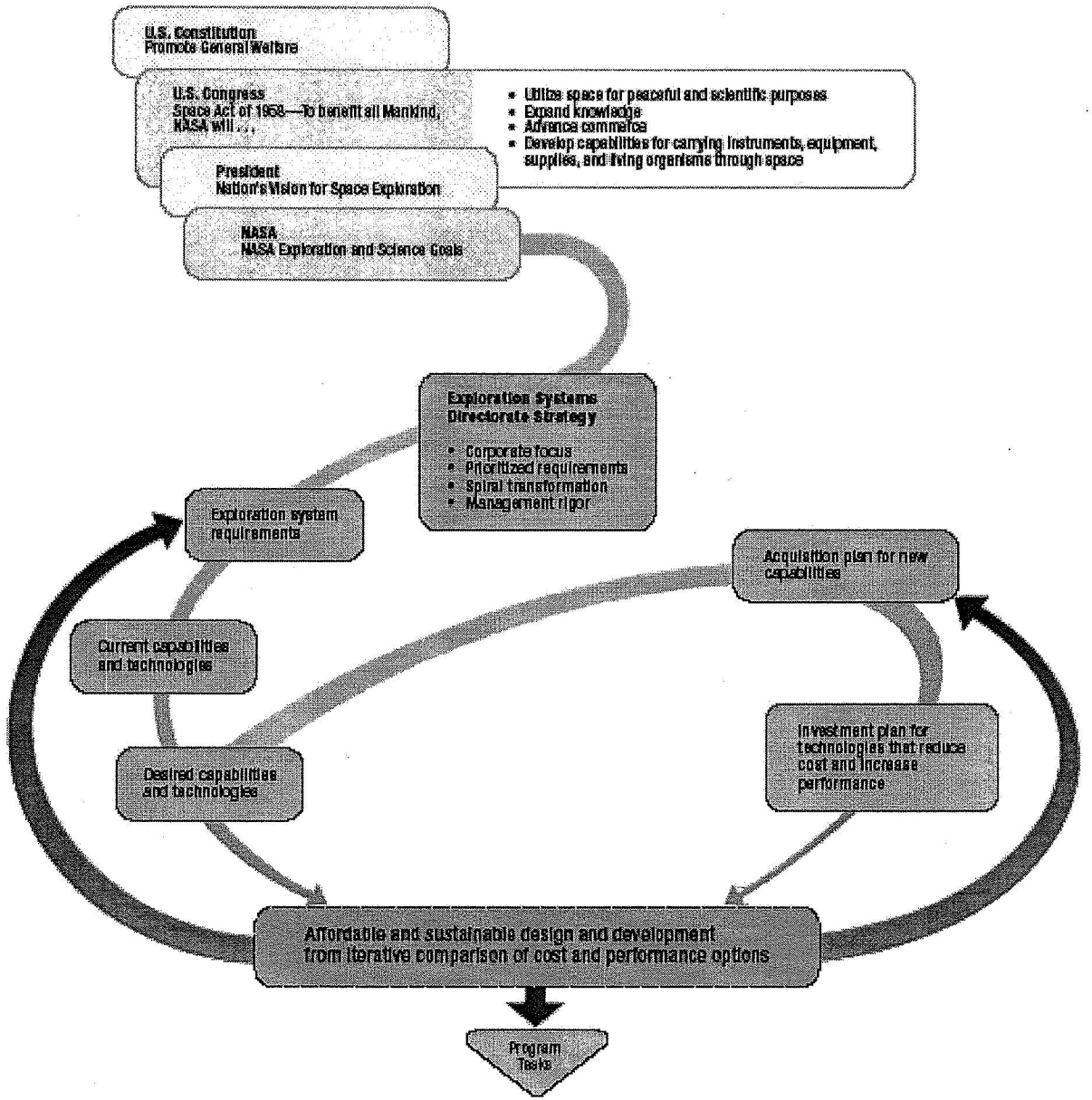


- Advanced Mission Operations
  - Precision Landing
  - Connectivity of pressurized modules
  - Autonomous spacecraft operations

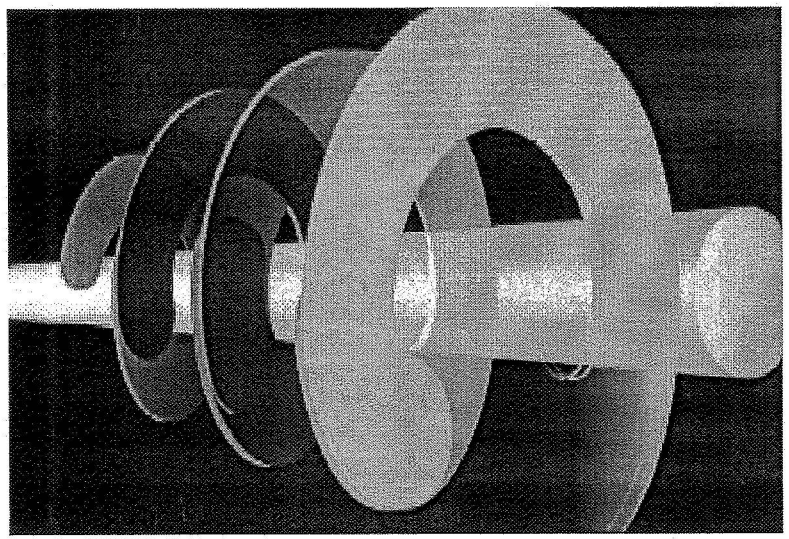


- Closed life support systems
  - Food (including plant growth)
  - Air
  - Water
- Develop confidence in integrated systems technology
- May reduce total program cost

From Policy to Strategy to Technology to Task



Spiral Development

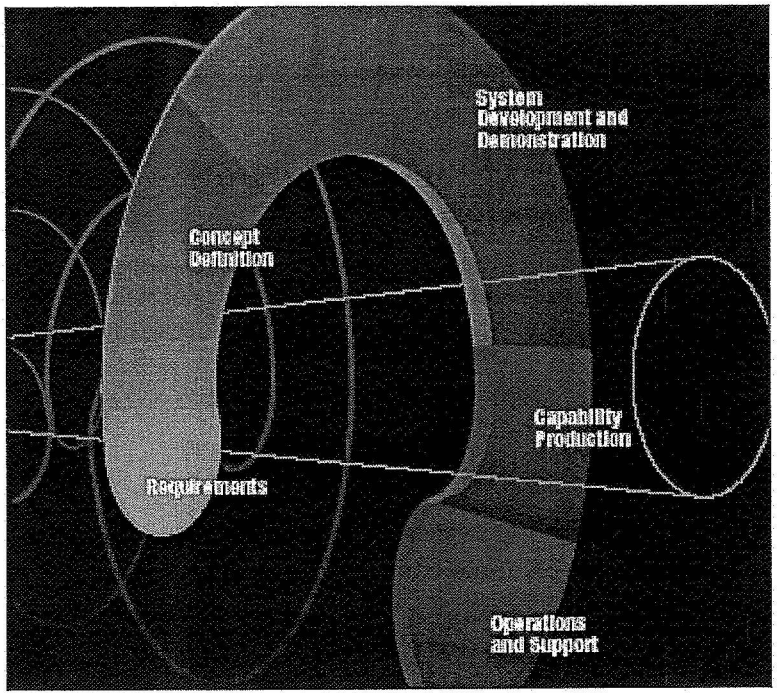


Capability development takes place within spirals that are concluded successfully with the delivery of needed capabilities.

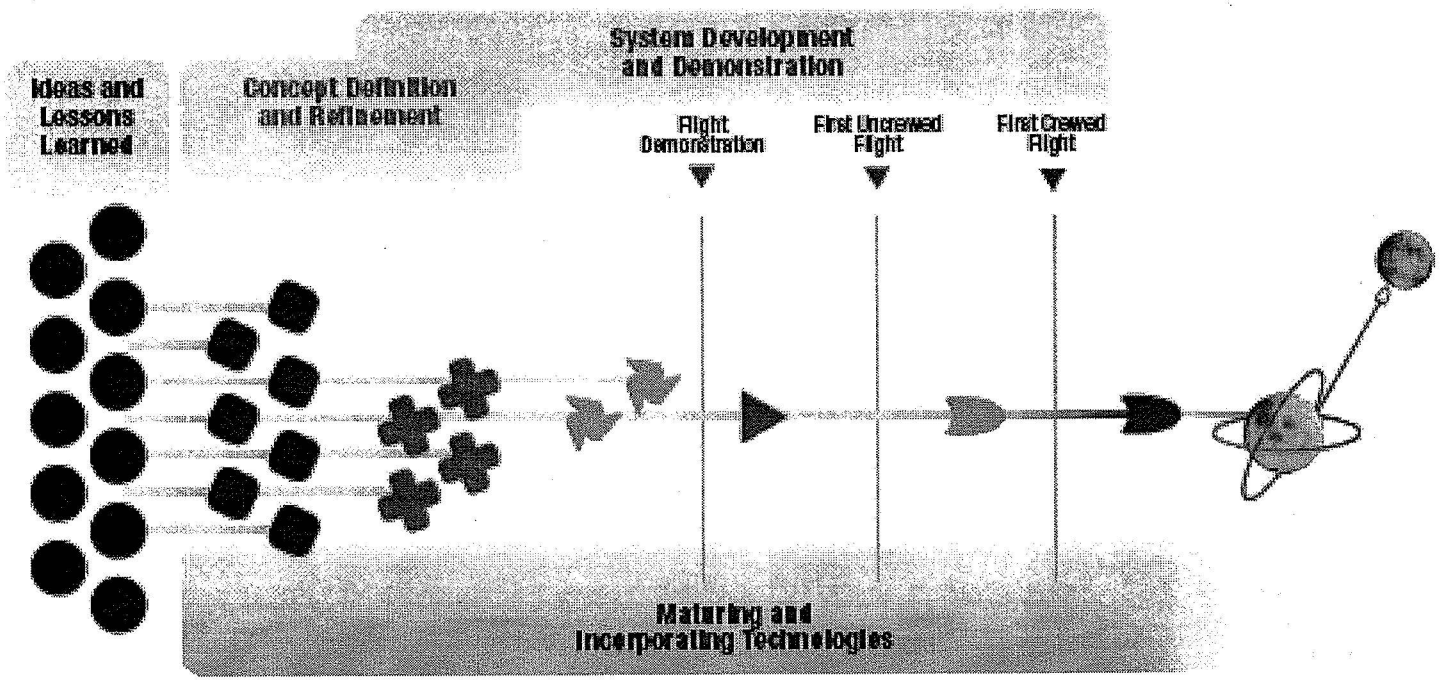
The first set of capabilities will encompass the CEV and lunar robotic missions that serve as a precursor for human exploration. These capabilities are an essential core around which greater capability will be developed in future spirals—so that NASA can conduct extended human missions to the Moon, and then to Mars and beyond.

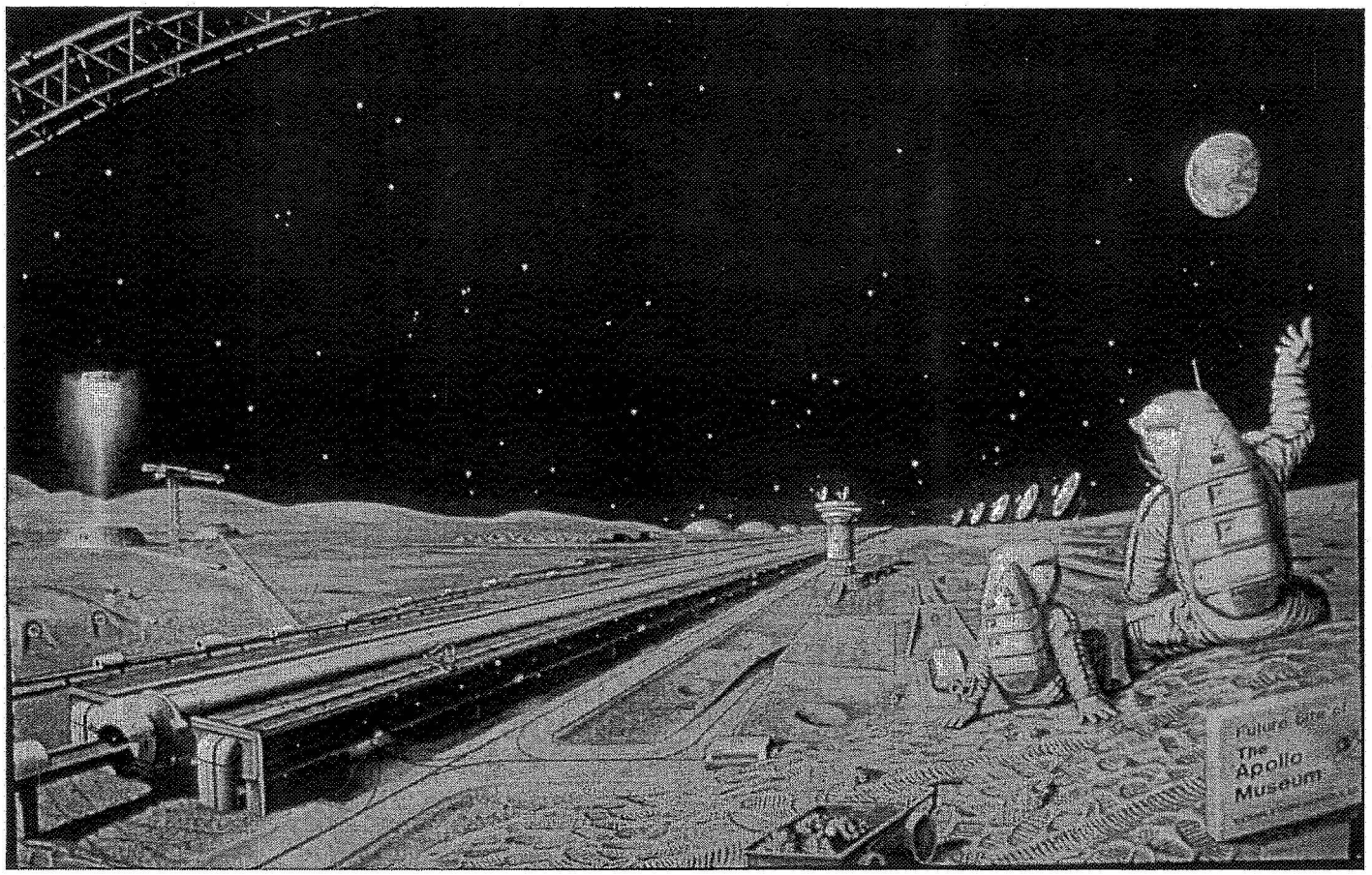
Requirements for new capabilities are established at the beginning of each spiral, followed by concept definition, systems development and demonstration, capability production, and operations and support.

Affordability is achieved through iterative risk assessments and technology gap analyses.

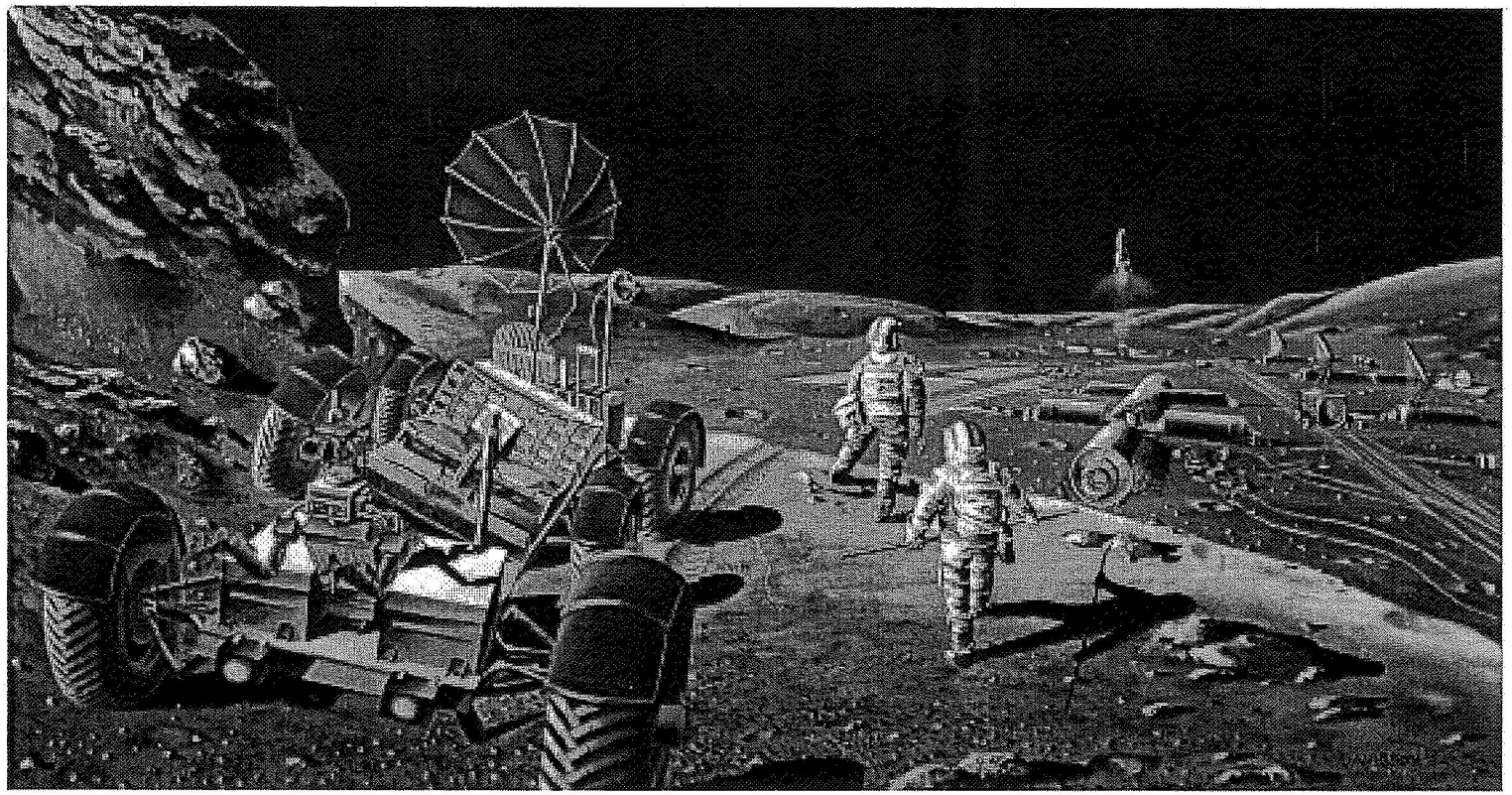


Developing the Crew Exploration Vehicle





"It's tough to make predictions, especially about the future."
—Yogi Berra



For more information regarding the Vision for Space Exploration, please visit our Web site
http://exploration.nasa.gov

Additional Information

Bioastronautics Critical Path Roadmap http://criticalpath.jsc.nasa.gov

Centennial Challenge Program http://centennialchallenges.nasa.gov

Columbia Accident Investigation Board http://history.nasa.gov/columbia/CAIB.html

Exploration Systems Mission Directorate http://exploration.nasa.gov

National Aeronautics and Space Administration http://www.nasa.gov

National Aeronautics and Space Administration Strategic Plan
http://ifmp.nasa.gov/codeb/docs/2003_Strategic_Plan.pdf

Nuclear Technology and Demonstration http://exploration.nasa.gov/proprom.html

Office of Biological and Physical Research http://spaceresearch.nasa.gov

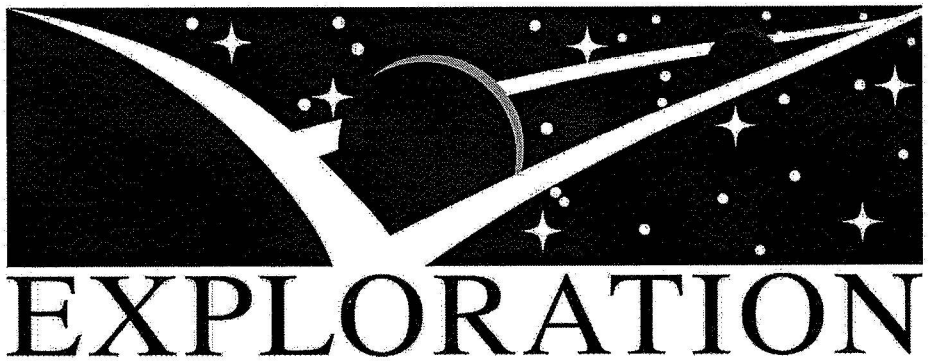
President's Commission on Implementing the Vision for Space Exploration
http://www.nasa.gov/pdf/60736main_M2M_report_small.pdf

Space Act—1958 Congressional Legislation http://www.hq.nasa.gov/ogc/spaceact.html

Small Business Innovation Research Program http://www.sbir.nasa.gov

TechFinder Database http://technology.nasa.gov/

Vision for Space Exploration http://www.nasa.gov/missions/solarsystem/explore_main.html


EXPLORATION